Studies in the New Zealand Hymenophyllaceae: Part 2—The Distribution of the Species throughout the New Zealand Biological Region.

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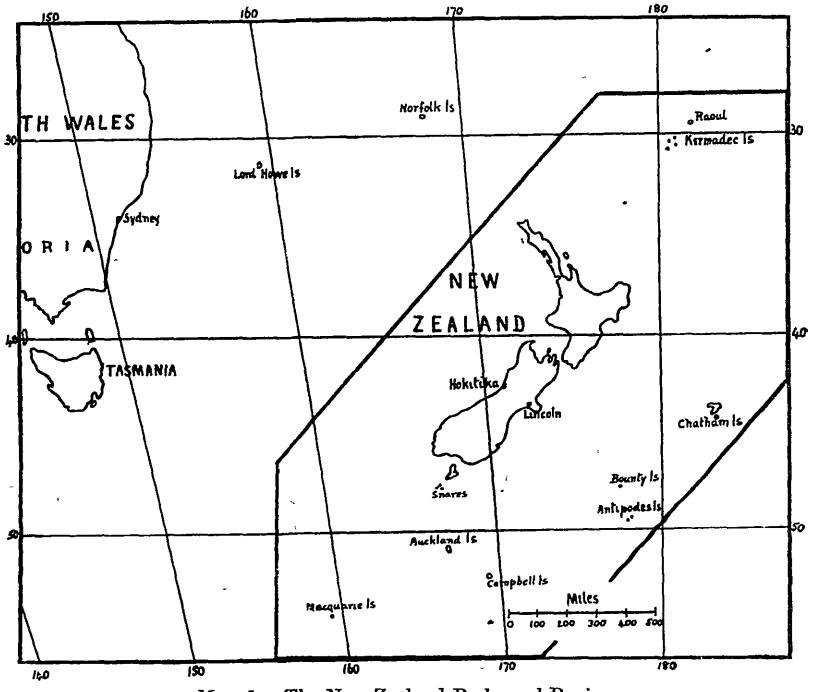
INTRODUCTORY.

IN a previous paper (18) I have given an account of my observations in the wet district of Westland on the distribution and growth-forms of the species of the New Zealand fern-genera *Hymenophyllum* and *Trichomanes*, including in it, from observations made in other parts of New Zealand, an account of the three species which apparently do not occur in Westland. Since the species occur at their optimum development in the humid forests and mountain ravines of Westland, the above-mentioned account will serve as a standard for comparison with ecological data concerning this fern-family gathered in other and drier districts of the New Zealand Biological Region.

In a well-known paper, entitled "The Geographical Distribution of Ferns," published in the *Transactions of the Linnean Society* in 1868, J. G. Baker observed that "with the precision of an hygrometer, an increase in the fern vegetation (it may be in species, or it may be in the number and luxuriance of individuals, but usually in both) marks the wooded humid regions." The filmy ferns, being as a family specially adapted to humid conditions, respond very quickly in their manner of distribution, and, in the case of many of the species, in their growth-forms also, to variations in the atmospheric humidity, as was shown in my paper quoted above. The species of this family, then, will undoubtedly serve as indicators of the climate of the forest-interior of any particular locality, and the indications will be found not only in the presence or absence of individual species, their comparative abundance and luxuriance, and in the growth-forms adopted by them, but also in the exact station taken up by them in the forest. In the present paper I propose to trace the distribution of the family more especially in the comparatively dry Eastern

Botanical District of the South Island of New Zealand (see map 4, p. 85), and to bring together the facts concerning their occurrence in the remaining parts of New Zealand and in the outlying islands which I have gathered from my own observations or are contained in various botanical papers in the *Transactions of the New Zealand Institute* and in other scientific publications.

The only really satisfactory meteorological data for use in such a study as the present one would be those recording the range in humidity in the forest-interior from day to day and from season to season, so that in this way a close comparison might be instituted between different types of forest and between different stations in the forest under varying conditions of climate and altitude, with a view to ascertaining both the minimum and the optimum



MAP 1.—The New Zealand Biological Region.

degree of humidity for each species. A large yearly rainfall might be found to characterize some locality which experiences an annual dry season, and under these conditions the filmy-fern flora would be scanty and local, there would be few epiphytes in the forest, and in a general way the forest-floor would be bare of all but the hardiest ferns. Even if there were no specially dry season in the year, extreme temporary fluctuations in the humidity—due, for example, to dry winds—would largely determine in any locality the distribution and growth-forms of the Hymenophyllaceae. Thus meteorological data to be of use by themselves in such a study as the present should be detailed, for it is evident that the Hymenophyllaceae for the most part need not only a high but a continuously high atmospheric humidity. It would be manifestly impossible to collect detailed data of this kind over so extended and varied a region as I am here dealing with,

so that I have had to fall back upon such evidence as is afforded by the actual rainfall data, supplemented by general climatic information, and by the study of the general fern and other forest vegetation present.

For a detailed list of the twenty-six New Zealand species reference must be made to my previous paper (18) and to the *Manual of the New Zealand Flora* (10). I take this opportunity of acknowledging the source of the rainfall map on page 73, which I have adapted from that issued by the Government Meteorological Office, and of the meteorological data, which I have culled from the regular publications of the Department; and also of L. Cockayne's map on page 85, which I have taken from his paper (14) on the proposed botanical districts of New Zealand.

I. The Climate, Forest-covering, and Distribution of the Hymenophyllaceae East of the Southern Alps.

From the meteorological data set out in Table A, on page 70, it is evident that the climate experienced at the east coast of the South Island is very different from that at the west. The total number of rainy days at Lincoln is only about three-fifths of that at Hokitika, and the rainfall is less than a quarter as much. This difference is reflected also in the greater number of hours of sunshine at the former than at the latter station. The most important climatic fact of all, however, is one that does not appear in the table—namely, that there is an almost complete absence of strong dry winds in Westland, at any rate so far as the lowlands are concerned, whereas in Canterbury the excessively dry and often fierce north-west wind is a characteristic, if intermittent, feature. The fact that Hokitika lies in the path of the prevailing westerly moisture-laden winds is accountable for the greater average daily wind-velocity recorded here than at Lincoln. It will be seen also that not only is the mean humidity noticeably less for Lincoln than for Hokitika, but the seasonal variation is more marked. Finally, the daily and also the seasonal range in temperature is less at Hokitika than at Lincoln. Humidity data, perhaps more than any other, need to be qualified with a statement as to the particular conditions under which they are taken. All the data given in Table A were taken in the open, and do not, of course, refer to actual forest conditions. However, they enable us to gain a good idea as to what those conditions will be. The lack of drying winds, the low summer temperature, the heavy rainfall, and large number of rainy days fairly evenly distributed over the whole year all point to the fact that in the Westland forests the humidity is more or less constantly high, and that transpiration from frond and leaf-surface will probably never be excessive. On the other hand, in Canterbury the strong dry winds will bring about such extreme fluctuations in the humidity that they may be regarded as one of the most important factors in the determination of the plant-covering. In the forest-interior also these fluctuations will be felt, and the fern flora and the station adopted by the individual species will be restricted thereby. The other climatic factors also will tend to make the atmospheric humidity in the Canterbury forests both lower and also more variable than in those of Westland, such as the very much smaller rainfall, the greater amount of bright sunshine, the hotter summer and the colder winter, and the greater daily range in temperature. From these facts it would follow that the forests of Canterbury would be less extensive than and different in type from those of Westland, and that the distribution in them of the Hymenophyllaceae and other fern-families would be more restricted.

TABLE A.

Meterological Data for Hokitika and Lincoln, situated on the West and East Coasts respectively of the South Island, New Zealand, giving the Means for the Period 1911–20 inclusive.

——	January.	February	March	April	May.	June.	July.	August.	September.	October.	November.	December.	Year
Rainfall, in inches—													
Hokitika	10·44	6·60	8·22	10·61	8·09	8·29	8·90	9·05	11·07	12·04	17·76	8·79	114·86
Lincoln	2·58	2·14	1·32	2·04	2·43	2·35	2·95	1·47	2·07	1·61	1·93	2·30	25·19
Rainy days—													
Hokitika	16·7	11·2	14·1	17·7	14·7	17·0	16·4	15·7	19·8	19·7	21·6	15·3	199·9
Lincoln	9·6	8·2	8·3	9·6	11·3	12·1	12·3	10·6	10·0	9·8	12·5	10·1	124·4
Mean humidity—													
Hokitika	77·0	77·6	76·5	76·3	73·2	75·9	73·1	72·9	75·5	77·7	79·6	79·5	76·3
Lincoln	68·2	70·8	69·3	71·9	74·5	76·5	76·7	74·9	71·6	69·6	69·5	68·2	71·7
Average daily velocity of wind, in miles—													
Hokitika (1911–19) ..	139·8	115·7	103·0	103·8	87·3	87·2	87·2	97·7	147·8	168·3	175·7	159·2	122·7
Lincoln	148·1	125·5	120·0	100·0	89·2	84·9	84·1	96·6	116·0	135·6	138·3	141·8	114·4
Sunshine, in hours and minutes—													
Hokitika (1913-20) .	192 24	177 26	177 27	130 37	141 55	101 44	109 20	153 32	135 26	162 6	171 36	217 41	1871 14
Lincoln .. .	217 85	188 12	197 5	152 45	137 55	113 40	124 73	153 50	176 5	218 5	208 32	213 65	2103 52
Shade temperature—													
Hokitika—													
Mean maximum ..	65·5	66·9	65·9	61·5	56·4	52·7	53·3	54·4	56·8	58·8	59·9	62·9	59·6
Mean minimum ..	51·5	52·6	51·1	47·5	40·3	38·2	37·6	37·9	42·6	45·4	47·0	49·1	45·0
Lincoln—													
Mean maximum .	72·5	71·1	69·4	64·7	65·8	53·0	52·0	54·0	59·3	64·5	66·6	69·5	63·5
Mean minimum ..	50·6	54·4	49·3	44·7	39·3	36·2	36·0	36·6	40·5	43·8	45·7	47·5	43·7

With regard to the forest-covering, it may be said generally that there is but the one type in Westland—namely, the very heavy mixed taxad rain forest. It is true that there are variations in this, such as the more open black-pine and white-pine stands of the river-flats, and the characteristic association of the higher mountain-flanks; but these can be regarded here as local varieties of the taxad rain forest. East of the dividing range, however, there is a considerable differentiation in the forest-covering, depending both upon altitude and upon general climatic conditions. The relation between the forest type and the soil-conditions cannot be entered into here. In Canterbury there is both rain forest and also dry southern-beech forest. On the eastern flanks of the dividing range the altitudinal factor is the stronger, and, although the rainfall is heavy, the rain forest is not taxed but mountain southern-beech. Cockayne and Laing have shown, however (16, p. 363), that at the source of the Rakaia River, on the eastern flanks of the main ranges, the mountain-totara and the kawaka form a very characteristic association which can be regarded as true western rain forest. I have preferred to consider the occurrence of the Hymenophyllaceae in this southern-beech rain forest apart from their occurrence in the Westland forests, although these two types of forest as they here occur belong to the same botanical district of L. Cockayne (14), and I have done this in order to reduce the problem of their distribution in Westland as far as possible to the simple question of the effect upon the family of altitude alone. In South Canterbury the outlying areas of rain forest lie at a lower altitude and are not southern-beech, but mixed taxads. On account of the moderate rainfall, however, they are less heavy than those of Westland, and lack a number of characteristic members of the Westland rain forest. In North Canterbury, where the north-west wind is most experienced, the dry southern-beech forest prevails, although this dry wind, of course, may not be the only cause determining its presence. Thus whereas in Westland the regional distribution of the Hymenophyllaceae is dependent, on the whole, upon the altitudinal factor alone, east of the dividing range there must be considered, in addition to the altitude, the type of forest present, and also the particular rainfall and general humidity conditions prevailing in each area of forest.

Table A, indicating the difference in the climate experienced at the west and east coasts respectively, is taken from Part I of these Studies.

A. *The Eastern Flanks of the Southern Alps.*

In my previous paper I have given a detailed account of the occurrence of the Hymenophyllaceae in the Otira Gorge and on the neighbouring mountain-sides at the western extremity of Arthur's Pass. I will now trace their distribution on the eastern side of the pass and on the eastern flanks of the dividing range in its vicinity (see maps on pages 73 and 76).

The rainfall at the eastern portal of the Midland Railway tunnel which pierces the range at this point, distant a little over five miles from the western (or Otira) portal, is somewhat less than that recorded for the latter locality. As at Otira, the main continuous rain comes from the north-west. In accordance with its higher altitude (viz., 2,435 ft.), more snow falls in winter at the eastern end of the pass than at the western (1,583 ft.). The rainfall diminishes rapidly farther down the Bealey River valley which descends from the pass in a south-easterly direction, and at the junction of the Bealey with the main Waimakariri River valley, and in this

latter valley itself, the north-west rain is experienced for the most part only as heavy intermittent showers. Table B gives the rainfall in inches and the number of rainy days at Otira, at the eastern portal of the tunnel, and at the Bealey accommodation-house respectively, for each month of the year 1914, from which a good idea can be gathered as to the diminishing of the rainfall eastwards. The Bealey accommodation-house is situated on the east side of the Waimakariri River at a distance of two miles from where the Bealey Valley opens out into the latter, and of twelve miles as the crow flies south-east of Otira, and at an altitude of about 2,000 ft. It lies just beyond the limit of the rain forest.

TABLE B.

Year, 1914.

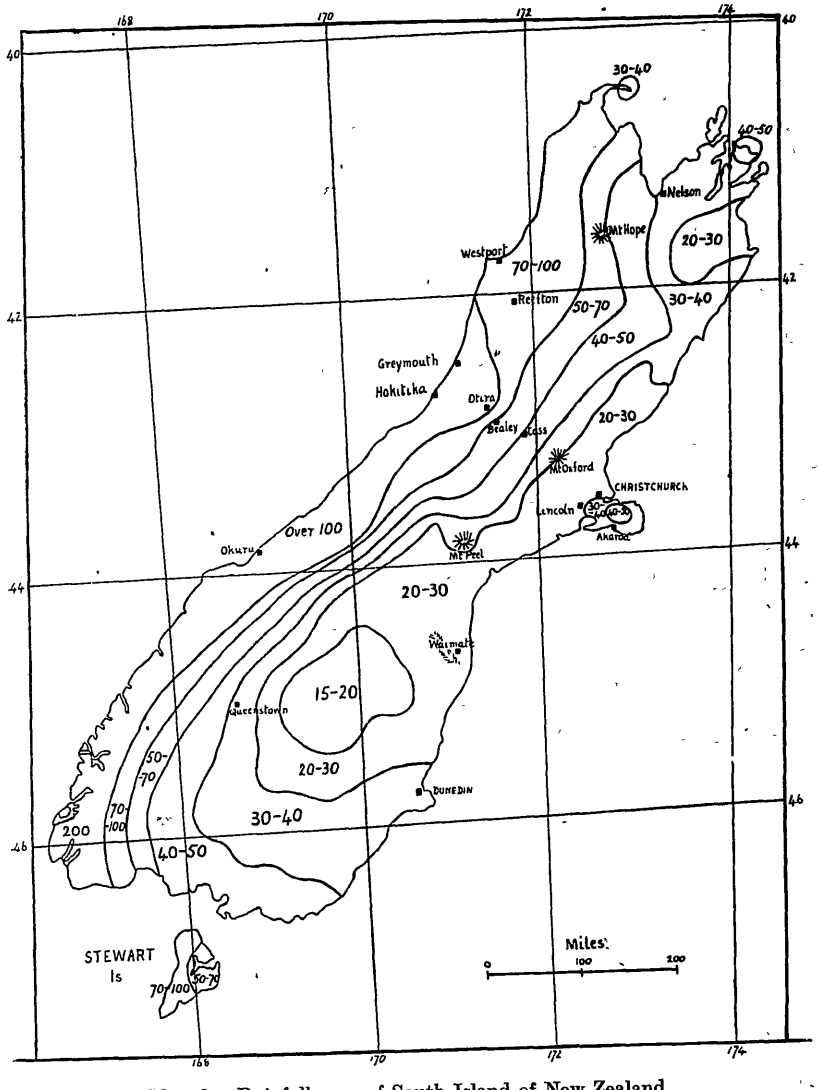
——	Jan.	Feb.	Mar	April	May.	June.	July.	Aug	Sept.	Oct.	Nov.	Dec.	Year.
Otira.													
Rainfall ..	19·44	7·63	4·05	25·67	15·08	7·96	10·50	12·03	17·99	12·31	24·14	36·09	192·89
Rainy days..	23	10	12	24	12	15	17	16	16	17	20	22	204
Eastern Portal of Tunnel.													
Rainfall ..	16·58	6·47	2·60	25·12	12·51	6·82	7·29	8·59	13·64	10·01	19·13	26·85	155·61
Rainy days..	20	9	12	23	12	15	14	12	14	15	16	20	182
Bealey.													
Rainfall ..	5·80	2·05	1·09	6·91	5·27	4·15	3·90	4·37	4·92	3·82	6·86	8·55	57·69
Rainy days..	12	8	7	9	—	4	9	10	5	10	13	13	100*

* 11 months

It may be added that the mean annual totals for these three stations for the period 1912–15 were as follows: Otira, 202·99 in. on 197·7 days; eastern portal, 174·80 in. on 193·2 days (March, 1915, omitted); Bealey, 67·40 in. on 115 days (May, 1914, omitted).

On the eastern flanks of the main range there is a continuous clothing of forest which consists practically solely of the mountain southern-beech (*Nothofagus cliffortioides*). The three characteristic tree-members of the Westland mountain forests—viz., the southern rata (*Metrosideros lucida*), the kawaka (*Libocedrus Bidwillii*), and the mountain-totara (*Podocarpus Hallii*)—are practically absent, although they occur somewhat scantily along with their seedlings and saplings amongst the *Nothofagus* on the eastern side of Arthur's Pass. The fact that the mountain-totara - kawaka association is found only in certain specially favourable localities on the eastern flanks of the divide (as noted above) must be taken as due primarily to a marked difference in the climate between west and east. The undergrowth of the southern-beech forests consists for the most part of the *Nothofagus* seedlings and saplings, although such large-leafed shrubs as *Nothopanax Colensoi*, *N. simplex*, *Phyllocladus alpinus*, *Griselinia littoralis*, &c., enter sparsely into its composition, more especially in the smaller gullies. The canopy of this *Nothofagus* forest is more or less open on account of the twiggy nature of the branches and the very small size of the leaves, and in considering its fern content the restrictive effect of this feature must be added to that of the climate generally. Moreover, the tree-trunk bases are for the most part regularly cylindrical and erect, and of small diameter, and accordingly do not provide the favourable stations for low epiphytes as

do the overhanging and irregularly growing large tree-bases of the southern rata and the mountain-totara. In spite of the heavy annual rainfall the floor of the forest is frequently dry, and on one occasion on which the writer examined the Bealey Valley forest it was noticeable how remarkably rapidly the forest-floor and the trees generally had become dry after two



MAP 2.—Rainfall map of South Island of New Zealand.

or three days of rain and snow, in spite of the fact that there had been no wind. In view of this it is not surprising that another prominent characteristic of the Westland forests is here absent—namely, the constant clothing of the boulders and fallen logs with ferns and liverworts.

Throughout this eastern mountain rain-forest *Hymenophyllum villosum* is fairly abundant both in moss on the floor and as a low epiphyte, the only other epiphyte being the small hardy *Polypodium Billardieri*, which also keeps to within a very few feet of the ground. *H. multifidum*, *H. flabellatum*, and *H. rarum* are also present, though much less commonly, and always on shaded rock-faces or in other overhung places, the two latter species in small stunted colonies. The only other ferns to be met with are the hardy and widespread *Polystichum vestitum*, *Blechnum penna marina*, and *B. vulcanicum* (these three being abundant), such rupestral species of *Asplenium* as are widespread throughout the drier parts of the South Island, and also the mountain *A. trichomanes*, although in damp gullies and hollows *Blechnum capense*, *Gleichenia Cunninghamii*, and *Asplenium bulbiferum* are not uncommon. It is noticeable that *Hymenophyllum demissum* and *H. bivalve*, which are frequent terrestrial or low epiphytic species in the western mountain forests, and are also most abundant in the southern-beech forests of Nelson up to an altitude of 3,000 ft., are here apparently altogether absent, although Armstrong (5) reported finding the former. Thus only those Hymenophyllaceae are present which in Westland were found to be able to adopt the high epiphytic station and the close mat growth-form, and of these only *H. villosum*, the hardiest species in the New Zealand family, is at all frequent.

On damp, moss-covered rock-faces in the forests of rather lower altitudes I have also occasionally found *H. pulcherrimum* and *H. peltatum*. These two species in Westland belong to the mountain ravines and do not descend to the lowlands. They are neither, however, especially hygrophilous, and *H. peltatum* is also a typical mat-former. Throughout the forests of the Eastern Botanical District the latter must certainly be included among the very few species which are at all abundant.

In addition to the Hymenophyllaceae enumerated above as occurring on the eastern flanks of the main divide, *H. Armstrongii* was originally discovered (4) alongside waterfalls near the source of the Waimakariri River at an altitude of 3,800 ft., and probably exists elsewhere also in similar localities. *H. Malingii* occurs almost invariably on old large trunks of the kawaka, and it has been reported from the kawaka forest noted above as occurring at the head of the Rakaia River. The peculiar frond-form of this species, as noted in my first paper (18), is well adapted to withstand drying.

B. *The Intermediate Montane Area.*

The neighbourhood of Cass (see maps on pages 73 and 76), which is situated on the Midland Railway at an altitude of 1,850 ft., may be taken as representing more or less typically those montane tussock-grasslands of Canterbury which lie between the dividing range and the more easterly outlying mountains. Through the kindness of Dr. C. Chilton, Professor of Biology at Canterbury College, I was able to stay for a few days at the College Biological Station at Cass, and from this as my centre to examine the neighbouring country, and also the forests of the Waimakariri Valley. I desire to express my thanks to Dr. Chilton for the opportunity thus given me, and also to Mr. C. E. Foweraker, of the Biological Laboratory, who accompanied me on these expeditions.

There is a rain-gauge at the Biological Station, which is read at intervals, and from the data thus gathered it seems clear that the rainfall is here somewhat less than at Bealey, which lies about six miles due west. The north-west showers frequently pass down the Waimakariri Valley, and so do not reach Cass, which lies two miles up a lateral valley. The

north-west winds, however, are frequent and drying, and at times very fierce. It is apparent, then, that Cass possesses a more severe climate than that which prevails on the eastern flanks of the dividing range. Cockayne and Laing have shown (16, p. 345) that these two climates, the subalpine forest and the tussock-grassland climate, pass into one another without a transitional phase, and that the sharply defined line which separates them extends throughout Canterbury at a short distance east of the dividing range. They add, "The steppe [*i.e.*, the tussock-grassland] climate is far from being really dry, but clear skies with strong insolation are frequent, and the ever-present wind would demand a much higher rainfall before forest could establish itself naturally." The following are the annual rainfall figures available with respect to Cass: 1917 (from 21st April), 38·7 in.; 1918, 59·8 in.; 1919, 40·6 in.; 1920, 43·0 in.

In accordance with these climatic conditions the southern-beech (*N. cliffortioides*) forest in the neighbourhood of Cass is present only in patches in the mountain-side gullies, the greater part of the area being covered by tussock-grass, divaricating shrubs, and subalpine herbs, and the river-terraces by mat and cushion plants and by the thorny *Discaria toumatou*. For a fuller account of the plant ecology of this area reference must be made to Cockayne and Foweraker (15). The interior of the patches of *Nothofagus* forest is very open and dry, and there are few shrubs. The few hardy ferns are more or less confined to the immediate neighbourhood of the watercourses, and epiphytes are altogether lacking. The only species of *Hymenophyllum* present is *H. villosum*, which occurs on the ground in moss near the creek-sides. Mr. Foweraker informs me that the same species is present in a very stunted form on rocks at the summit of Mount Sugarloaf, in the immediate vicinity of Cass, at an altitude of about 4,000 ft.

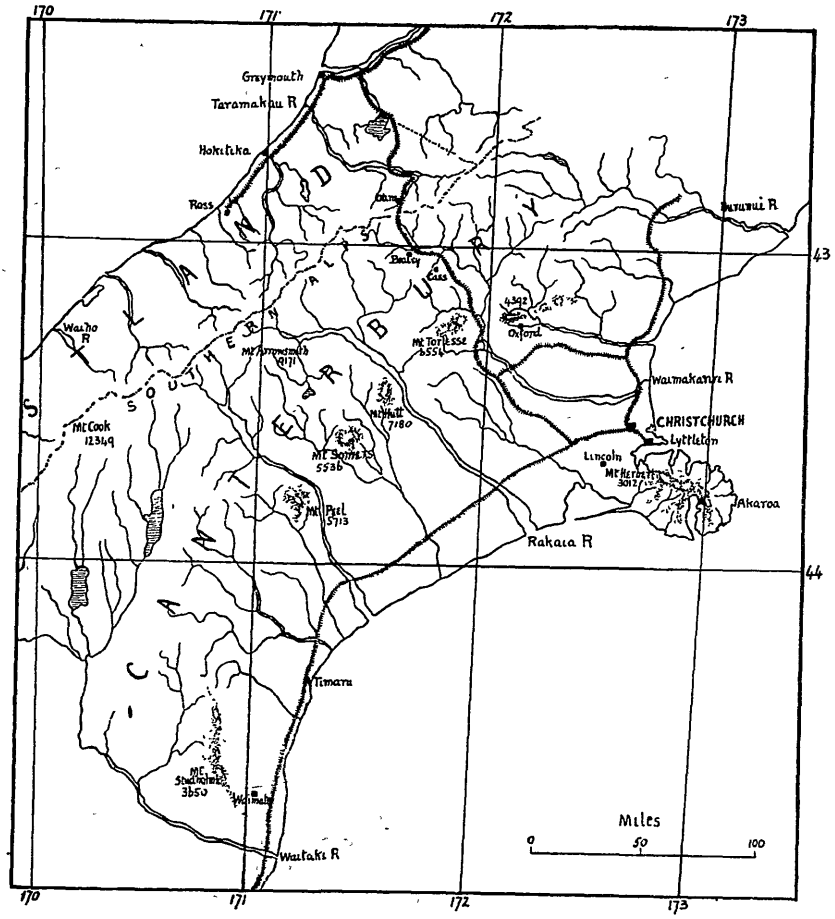
In their account of the plant ecology of the Mount Arrowsmith district (see map 3, on page 76), which lies between the upper Ashburton and Rakaia Rivers, a few miles to the east of the boundary of the Western Botanical District, Cockayne and Laing (16, p. 357) note the presence at subalpine altitudes of *H. villosum* as a special rock-plant, and *H. multifidum* on peaty humus on rock-ledges and in chinks. Dr. Cockayne informs me that on the wetter mountains of Central Otago (see map 4, on page 85) *H. multifidum* occurs in its mountain form in sheets on shady rocks at altitudes of 3,000 ft. and upwards.

C. *The Eastern Outlying Mountains of Canterbury.*

From map 3, on page 76, it will readily be seen that separating the intermediate montane area of Canterbury from the eastern plains there is a chain of high outliers, separated from one another by the main river-valleys. These outliers are forest-clad on their seaward slopes. I propose now to give a description of the distribution of the Hymenophyllaceae in the forests of three of these outliers—viz., Mount Oxford in the north, Mount Peel and Mount Studholme in the south—adding also what is known as to their occurrence in the original forests of Banks Peninsula.

As has already been mentioned, the presence of continuous forest on the eastward slopes of these outliers, which in the case of South Canterbury, and also of Banks Peninsula, must be reckoned rain forest, is due to the easterly and south-westerly precipitation in addition to the occasional north-west showers. The fierce and drying nature of the north-west winds is experienced rather in the northern than in the extreme southern parts of Canterbury. I am informed by Mr. F. Akhurst, the meteorological

observer at Waimate, that there the prevailing winds are light east and north-east, with light rain, the heaviest rains coming from the south-west; while the north-west winds only very occasionally pass beyond the interior, and even then have lost their violence. At Mount Peel also the greater part of the rainfall is derived from the south-west, although here the north-west winds sometimes bring heavy showers. On Mount Torlesse and Mount Oxford and farther north there is less of the steady south-west rain and more of the north-west showers, and the significance of this lies



MAP 3.—Canterbury, N.Z., showing outlying mountains.

in the fact that the latter, being accompanied by heavy winds, must be accounted of much less value to the vegetation than the former. There is a continuous and fairly heavy rain forest on Mount Peel, from which the southern-beech, except for certain isolated patches at higher altitudes, is absent, and also the flats and the sides of the near hills at Waimate were covered originally by the same type of rain forest; but the lower slopes of Mount Torlesse, Mount Oxford, and the lesser outliers still farther north are clothed with a typical southern-beech (*N. Solanderi*) forest intermixed with scattered taxads.

Table C gives a general idea as to the greater amount of precipitation that takes place on these outliers and on Banks Peninsula than at Lincoln on the plains. It must be noted that at Oxford, Peel Forest, and more especially at Waimate, the meteorological observers are located at distances varying from two to five miles east of the mountain-base, and at Akaroa the data refer to sea-level. Undoubtedly, therefore, in each case the figures will show a lower rainfall than what is actually experienced on the mountain-slopes. This conclusion is well attested by data kindly supplied me by Mr. F. Akhurst, giving the rainfall for the period 1911–20 at three different stations in the Waimate district—viz., "Greylands," Waimate, and "Hiwiroa"—of which the first named lies three miles farther east than Waimate, and the last two miles west of Waimate in the direction of the hills. These data show that there is a very consistent increase in the precipitation as one passes westwards from "Greylands" towards the hills, the mean annual totals at the three stations for the period 1911–20—viz., "Greylands," 22·91 in.; Waimate, 26·02 in.; and "Hiwiroa," 29·74 in.—indicating very fairly what this increase usually amounts to.

TABLE C.

Years 1911–20.

——	Oxford (750 ft.).	Peel Forest (900 ft.).	Waimate (180 ft.)	Akaroa (Sea-level).	Lincoln (42 ft.).
Mean annual rainfall ..	33·91	43·53	26·02	39·86	25·19
Mean number of rainy days	113·40	118·80	129·70	93·00*	124·40

* For 1917–20 only (one month omitted from 1919 and 1920).

Whereas in Westland and on the eastern flanks of the dividing range the forest is still practically virgin, on the outlying Canterbury mountains it has been largely cut out, or even, as on Banks Peninsula, almost wholly altered or destroyed. However, the fact that there are extensive and practically untouched scenic or water-supply reserve blocks at Mount Oxford, Mount Peel, and Mount Studholme makes it possible to gain a reliable idea as to the original distribution of the Hymenophyllaceae in these localities.

(*a.*) At Mount Oxford the reserve forest covers the area included in the Cooper's Creek watershed as it now exists, stretching in altitude from about 1,000 ft. to 2,500 ft. As usual in southern-beech forest, the undergrowth is composed mainly of the beech seedlings and saplings, though a few shrubs, such as small-growing *Griselinia littoralis* and small-leaved coprosmas, are scantily present. In the narrow lateral gullies these shrubs are rather more abundant, and include the large-leafed araliads *Nothopanax arboreum* and *Schefflera digitata*, and occasionally also the small-growing tree-fern *Alsophila Colensoi* and the larger *Cyathea dealbata*. For the most part the forest-floor is open and dry, there are no epiphytes, and the ferns are confined to the smaller gullies and to the steep sides of the main stream-bed.

Apparently only four species of *Hymenophyllum* are present. Of these *H. villosum* and *H. multifidum* are abundant in close colonies on the rocky walls of the main gully and on the mossy forested sides of all the gullies generally. Both are to be found also, though less frequently, on the mossy floor of the terrace-forest, where the only other ferns present are the hardier species of *Blechnum*. *H. sanguinolentum* is the only lowland

species present; and this is restricted to one or two especially damp localities in the lower part of the main gully. *H. peltatum* is not uncommon at rather higher altitudes in close mats on boulders and on the rocky sides, more especially in secluded gullies. Such ferns as were found to occur commonly in the southern-beech forests on the eastern flanks of the dividing range are present here on the main gully-walls, and in addition abundant *Polypodium grammitidis*. Intersecting the terrace in the main valley are several narrow and damp gullies in which such hygrophilous and shade-loving ferns as *Blechnum Patersoni*, *Dryopteris pennigera*, and *Leptopteris hymenophylloides* are commonly present. A few days previous to my visit there had been an unusually violent dry north-west gale, and even in these secluded gullies its effect had been felt, for the edges of the fronds of the *Leptopteris* were shrivelled. In the more open main gully and on the forest-floor generally, where the drying effect of the wind must have been severe, neither *H. villosum* nor *H. multifidum* showed signs of shrivelling, thus bearing witness to their hardy nature.

From a locality, now denuded of forest, at a somewhat lower altitude Mr. G. Anderson, of West Oxford, has kindly sent me specimens of both *H. minimum* and also stunted *H. Tunbridgense* which were growing scantily on a rock-face in a creek-bed. As shown in my previous paper, the former species has a fairly wide range in Westland, but the latter is a lowland plant. The presence of these two additional species suggests that in the original Oxford forest—at any rate, at its lower levels—still other species, as, for example, *H. sanguinolentum*, may have been present on damp rock-walls in the watercourses, but in the existing forest the distribution is practically restricted to the three species which throughout the Canterbury forests are the most widely occurring of all.

(*b.*) With respect to Peel Forest my own observations are supplemented by those of Dr. H. H. Allan, who has made a special study of the plant ecology of this area. The higher humidity of Peel Forest as compared with that of Mount Oxford is clearly shown in the fact that the ferns which in the Oxford forest gullies are altogether rupestral are here abundantly present as epiphytes in thick moss on the shrubby trees in the Kowhai Creek bed at corresponding altitudes, and the more hygrophilous species are luxuriant on the mossy creek-sides. The three filmies, *H. villosum*, *H. multifidum*, and *H. peltatum*, which are all widely distributed throughout the Eastern Botanical District, are here abundantly present both as epiphytes, and also, in the case of the two latter, in sheets on the gully-walls. *H. villosum* adopts altogether the epiphytic station, climbing the shrubby trees in the creek-beds to a height of 15 ft., and always overtopping the other two species. *H. demissum* is also present in frequent terrestrial colonies, and *H. sanguinolentum* is occasionally to be found as a low epiphyte. The outstanding feature in the Hymenophyllaceae of Peel Forest, however, is the presence of *H. pulcherrimum* on the walls of the Kowhai Creek Gully throughout its entire length, and of *H. scabrum* in large sheets on the gully-sides in one or two especially secluded places. The former of these two species, as has already been stated, keeps almost entirely to mountain ravines, but yet is not an extreme hygrophyte. However, its marked abundance and luxuriance in the Peel Forest gullies is a significant feature. *H. scabrum* is undoubtedly a more hygrophilous plant, and its presence is an even clearer indication of the constantly high humidity of these gullies. On the forest-reserve slopes *H. flabellatum* occurs scantily on the bases of the stems of the tree-fern *Hemitelia Smithii*, but *H. multifidum* is the only species which is at

all abundant outside the actual gullies, spreading in sheets on the damp forest-floor. Above the forest-line, according to Dr. Allan's observations, this latter species, with *H. villosum*, occurs on damp rock-surfaces up to an altitude of about 4,500 ft. Compared, then, with the forest of Mount Oxford, that of Mount Peel shows itself in its Hymenophyllaceae to be quite of the rain-forest type, this being apparent both in the number of species and of individuals, and also in the station adopted by many of them. Compared, on the other hand, with their occurrence in the Westland forests, the species here are seen to be by no means the most hygrophilous of the family, and are also almost altogether those which have in Westland a wide altitudinal range or are purely upland plants. Moreover, they do not extend outside the narrow gully-beds to any marked extent, and their vertical range is restricted.

(*c.*) The largest extent of forest now existing in the Waimate neighbourhood is that in the water-supply area of Kelsey's Valley. This valley extends eastwards for a length of about two miles from the foot of Mount Studholme (3,650 ft.), in the Hunters Hills. At its lower end, distant four miles from Waimate, it lies at an altitude of 550 ft., and at the foot of Mount Studholme at about 1,400 ft. This forest, therefore, differs from that of Mount Peel and Mount Oxford in belonging almost wholly to lowland altitudes. As indicated above, its rainfall will be considerably greater than that recorded for Waimate itself.

From the lower end of the valley upwards there is the same general epiphytic fern flora on the shrubby trees in the stream-bed as at Peel Forest, although the stems of the tree-ferns are for the most part bare. The presence in the lower third of the valley of the three species *Hymenophyllum sanguinolentum*, *H. australe*, and *H. Tunbridgense*, the first named as an abundant low epiphyte, and the two others more scantily on the gully-walls, marks this locality as belonging to the lowlands. Farther up the valley, where also the shrubbery becomes more closed in, and the humidity, as evidenced by the wealth of mosses and liverworts, is higher, the upland species *H. villosum* and *H. peltatum* are predominant, the former being both low epiphytic and terrestrial, and the latter restricted entirely to the walls of the gully. *H. bivalve* and *H. multifidum* are also here present in thick moss on the creek-sides, and *H. demissum*, though somewhat less commonly. Although the characteristically lowland and upland members of this list are, as already indicated, predominant in the lower and in the higher reaches respectively of the main ravine, *H. sanguinolentum* is scantily present in one or two places as a low epiphyte up to 1,200 ft., and *H. peltatum* extends, but also scantily, well down into the lower reaches. The humidity, then, of the actual ravines of Kelsey's Valley will be, on the whole, somewhat lower or perhaps more variable than that of the Kowhai Creek at Mount Peel, this being clearly seen from a comparison of the list of species of Hymenophyllaceae present in each locality and in the degree of epiphytism shown by them. Moreover, the general facies of these two lists corresponds with the altitudes of the two localities as given above, using the facts concerning the behaviour of the species in Westland as a standard for comparison. As in Mount Peel, the Hymenophyllaceae in Kelsey's Valley are restricted to the deeper ravines, this being probably the case also in the original state of this forest.

(*d.*) The forests of Banks Peninsula have now nearly all been destroyed, so that it is not possible to describe with certainty the distribution of its filmy-fern flora. Laing (25) has carefully studied this area in its present

state, and has brought together what can be known from both present and past researches of the primitive state of its plant-associations. Martin (26) has still further studied the Pteridophytes of the Peninsula, and has succeeded in adding to the information contained in Laing's paper. J. B. Armstrong (5), in a general account of the flora of the Canterbury Province, published in 1879, when the forests were still largely untouched, gave special attention to the fern flora of Banks Peninsula. The following summary is based upon these three papers :—

The ridges, slopes, and valleys of the greater part of the Peninsula were originally covered with a continuous sheet of rain forest up to about 2,500 ft., the summits of a few of the highest peaks (*e.g.*, Mount Herbert, 3,014 ft.) alone rising above it. Up to 2,000 ft. the composition of this forest was very much that of the lower slopes of Mount Peel, except that the rimu also was scantly present, as well as certain characteristic northern trees and other plants. The lower stories were more closed in than in the case of any of the other forests of the Eastern Botanical District, there being a greater variety and abundance of shrubby trees and tree-ferns. Lianes and epiphytes were abundant, more especially in the gullies, and the tree-fern stems were commonly clothed with species of Hymenophyllaceae. The forests of this area certainly provided a more favourable home for the Hymenophyllaceae than those of the Eastern Botanical District already considered. This fact accords well with the geographical position of Banks Peninsula (see maps 2 and 3, on pages 73 and 76), and also with the general rainfall data recorded at Akaroa at sea-level (see Table C, on page 77).

Moreover, the strong, dry, north-west winds are less frequent and less severe on the Peninsula than on the plains, and in the gullies would have comparatively little effect. Thus its climate approaches nearer to that of Westland than that of any other part of the Eastern Botanical District. However, as Laing has pointed out (25, p. 364), the absence from the Peninsula of such common Westland trees as the southern rata (*Metrosideros lucida*), the kamahi (*Weinmannia racemosa*), and *Phyllocladus alpinus*, all of which are abundant also in the damp forests of Southland, is a sign of its drier climate. There is no doubt also that its filmy ferns were more restricted to the gullies, and were less epiphytic in habit, than in Westland.

In his list (5, p. 346) of the Hymenophyllaceae of the Peninsula, Armstrong enumerates, among others, all those species which have been described above as occurring elsewhere in Canterbury, with the exception of *H. villosum*, which species, however, Laing has found to occur on one of the peaks. In addition Armstrong mentions the following: *H. rarum*, *H. dilatatum*, *H. ferrugineum*, *H. Malingii*, and five species of *Trichomanes* —viz., *T. Lyallii*, *T. humile*, *T. venosum*, *T. elongatum*, and *T. Colensoi*. Of the species thus enumerated a considerable number have been reported also by Laing and Martin. It would seem, as Laing sets forth in detail (25, p. 372), that certain of Armstrong's identifications, more especially with regard to the flowering-plants, are to be doubted. So far as the Hymenophyllaceae are concerned I see no reason for doubting any of the members of the list, although Laing queries three species of *Hymenophyllum* and four of *Trichomanes*. Of these *T. humile* and *T. elongatum*, as has been mentioned earlier, are typically northern species. They are absent from Westland, but Cheeseman (10) records them from various localities in the Nelson and Marlborough Provinces. Seeing that there is a strong northern element in the Peninsula flora, it is not unlikely that these two species originally occurred there. Martin records the fact that a collector other

than Armstrong has reported the occurrence of *T. humile*, and he has very kindly forwarded me specimens of this species from this collection. *T. Colensoi* also is mentioned by Martin as having been reported by the same collector, and of this species also he has kindly forwarded me specimens said to have been gathered on the Peninsula. If the hygrophilous *T. Colensoi* was present there would seem to be no climatic reason why *T. Lyallii* also should not have been there. On the other hand, the apparent absence of *T. reniforme* is rather remarkable. As has been shown in my previous paper, this species is less hygrophilous than the other two members of its group—viz., *H. dilatatum* and *H. scabrum*—and, moreover, Armstrong has recorded it (5, p. 346) from elsewhere in the Canterbury Province. The presence on the Peninsula of *T. venosum* on tree-fern trunks has been corroborated by Laing. Of the three species of *Hymenophyllum* in Armstrong's list queried by Laing—namely, *H. scabrum*, *H. pulcherrimum*, and *H. ferrugineum*—the two former still exist in Peel Forest, and the latter would find a very suitable home along with *T. venosum* on the abundant tree-fern stems in the temperate humid gullies of the Peninsula.

I have to thank Professor A. Wall, of Canterbury College, for drawing my attention to the fact that *H. rarum*, *H. sanguinolentum*, and *H. Tunbridgense* all occur on the damp, shaded southerly faces of the Mount Pleasant lava-rocks overlooking Lyttelton, at an altitude of about 1,500 ft. The two former I found to adopt there the same stunted mat form in which they are found in Westland as high epiphytes, and *H. Tunbridgense* also was in very close mats on the vertical rock-faces.

It seems clear that originally the forests of Banks Peninsula possessed a filmy-fern flora which was very rich in species, but which was probably largely confined to the gullies. Compared with the other Eastern Botanical District forests, the outstanding feature was the presence of the greater number of the species of *Trichomanes*, and, generally speaking, of those members of the family, both lowland and upland, which are especially hygophilous.

D. *Comparison with Westland.*

In the wet forests of Westland the Hymenophyllaceae as a whole are epiphytic rather than terrestrial. East of the dividing range, on the other hand, though probably originally to a less extent on Banks Peninsula than elsewhere, the terrestrial station is that characteristically adopted by them.

At subalpine altitudes in Westland it was found that *H. villosum* alone tends to preserve the epiphytic habit, and this is to be seen also in the eastern subalpine rain forest. The difference in humidity between the southern-beech forest of Mount Oxford and the rain forests of Mount Peel and Waimate is brought out in the fact that in the former *H. villosum* is invariably restricted to the ground, together with the other few species present, whereas in the latter not only this species but also *H. multifidum*, *H. peltatum*, and *H. sanguinolentum* are able to adopt a low epiphytic station in deep shaded gullies. The species which in the Mount Peel and Waimate rain forests are able to adopt the low epiphytic station belong to that group which in the lowlands of Westland ascend to the tops of the highest trees, with the addition of *H. peltatum*, which in the ravines of the western flanks of the dividing range occurs as a low epiphyte in company with *H. villosum* and *H. multifidum*. No doubt in the humid gullies of Banks Peninsula, on account of the more equable climate, the Hymenophyllaceae were epiphytic to an even greater extent than at Peel Forest or Waimate.

To pass from the vertical to the regional distribution of the species east of the dividing range: Practically the only early source of information dealing with the forests in their less altered state is Armstrong's paper quoted above. In it he gives a list of Hymenophyllaceae which were to be found in the Canterbury Province, and he particularizes in a tabular form where each species occurred—whether on Banks Peninsula, or in the "Middle District," or in subalpine localities—and also whether they were rare, local, or abundant. It is evident from this list and from my own observations detailed above that, speaking generally, the species of *Trichomanes*, and also the specially hygrophilous species of *Hymenophyllum*, both lowland and upland, are either absent or are very locally distributed. *H. villosum* and *H. multifidum*, which in Westland have the widest altitudinal range, are, together with *H. peltatum*, the most abundantly distributed species east of the dividing range.

There are now no forests on the Canterbury Plains which can be described as altogether lowland and properly to be compared with the lowland forests of Westland. Owing to its dry southern-beech type, as well as to its altitude, the Mount Oxford forest now apparently contains only two lowland species, of which *H. sanguinolentum* is in every sense extremely restricted and *H. Tunbridgense* almost extinct. These two species are found here only at the lowest altitude. The rain forests of Mount Peel, Waimate, and Banks Peninsula, whose lowest altitudes are 1,000 ft., 550 ft., and sea-level respectively, show a corresponding increase in the number and comparative abundance of lowland species.

H. villosum does not in Westland descend to sea-level, and it preserves in Canterbury this character in its distribution. Judging from his list, Armstrong recognized *H. villosum* only in its more stunted subalpine form. In his original paper describing this species T. Kirk (22, p. 395) notes that collectors had commonly mistaken it for *H. ciliatum*, a species which has never been found in New Zealand since it was first reported from a single locality in the Nelson district some years before Armstrong wrote his paper. It is to be noticed that the latter includes *H. ciliatum* in his list, stating that it occurs in Canterbury at middle altitudes. I feel satisfied that he also must have mistaken, in some localities at least, *H. villosum* for the closely related *H. sanguinolentum*, and that he accordingly concluded that this latter species was widely distributed from the lowlands to subalpine altitudes. Again, he ascribes the same wide distribution to *H. Tunbridgense*, and I suggest that he has confused this species with *H. peltatum*. I have found the former to be a lowland and quite a local plant in Canterbury.

With regard to other usually widely-ranging species, it is noteworthy that *H. demissum*, which in Westland is abundant from sea-level to high up into the mountain forest, is very much less frequent in Canterbury. *H. bivalve* also, which occurs with *H. demissum* on the mountain-flanks of north Westland, and especially, as will be seen later, in the southern-beech forests around Nelson, is in Canterbury an infrequent species. Other widely-ranging species in Westland are the diminutive *H. Armstrongii* and also *H. rarum* and *H. flabellatum*. The former has been found in Canterbury only on wet mossy rocks and boulders in subalpine localities on the dividing range, as mentioned above. In the Westland lowlands it is extremely abundant in short moss on smooth sapling-like stems, but in the Canterbury forests such a station is not consistently damp enough. *H. rarum* and *H. flabellatum* are thoroughgoing epiphytes which can only

grow in a pendulous position. In Canterbury they have just as wide a range as in Westland, but are very local. *H. Malingii* occurs in Westland from sea-level to the subalpine forests wherever the kawaka is present. In Canterbury it seems originally to have had the same range, being reported from Banks Peninsula by Potts (30, p. 359) as occurring on the decayed trunks of both the kawaka and the mountain-totara, and from the valley of the Wilberforce River on the eastern flanks of the main ranges by F. N. Adams (see reference in Cockayne and Laing, 16, p. 343), in which locality the kawaka is the dominant tree.

The southern-beech type of forest is less favourable for the Hymenophyllaceae than is the mixed rain forest; but the comparison of the different forest types in the Eastern Botanical District with respect to their filmy-fern content is not quite so simple in the Eastern Botanical District as it will be seen to be in certain parts of the North-western District, for in the former the effect of forest type on the distribution of the Hymenophyllaceae cannot be studied apart from the effect of both altitude and general climate.

II. The General Distribution of the Species in other Parts of the New Zealand Biological Region.

Having given a detailed account of the Hymenophyllaceae as they occur in Canterbury under different conditions of climate, altitude, and forest covering, and compared these facts with their occurrence in Westland, it becomes less necessary to describe in so detailed a way their occurrence in other parts of the New Zealand Biological Region. The following summarized facts will serve to check or amplify the conclusions which have thus far been reached in this and in my previous paper with regard to the behaviour of the species.

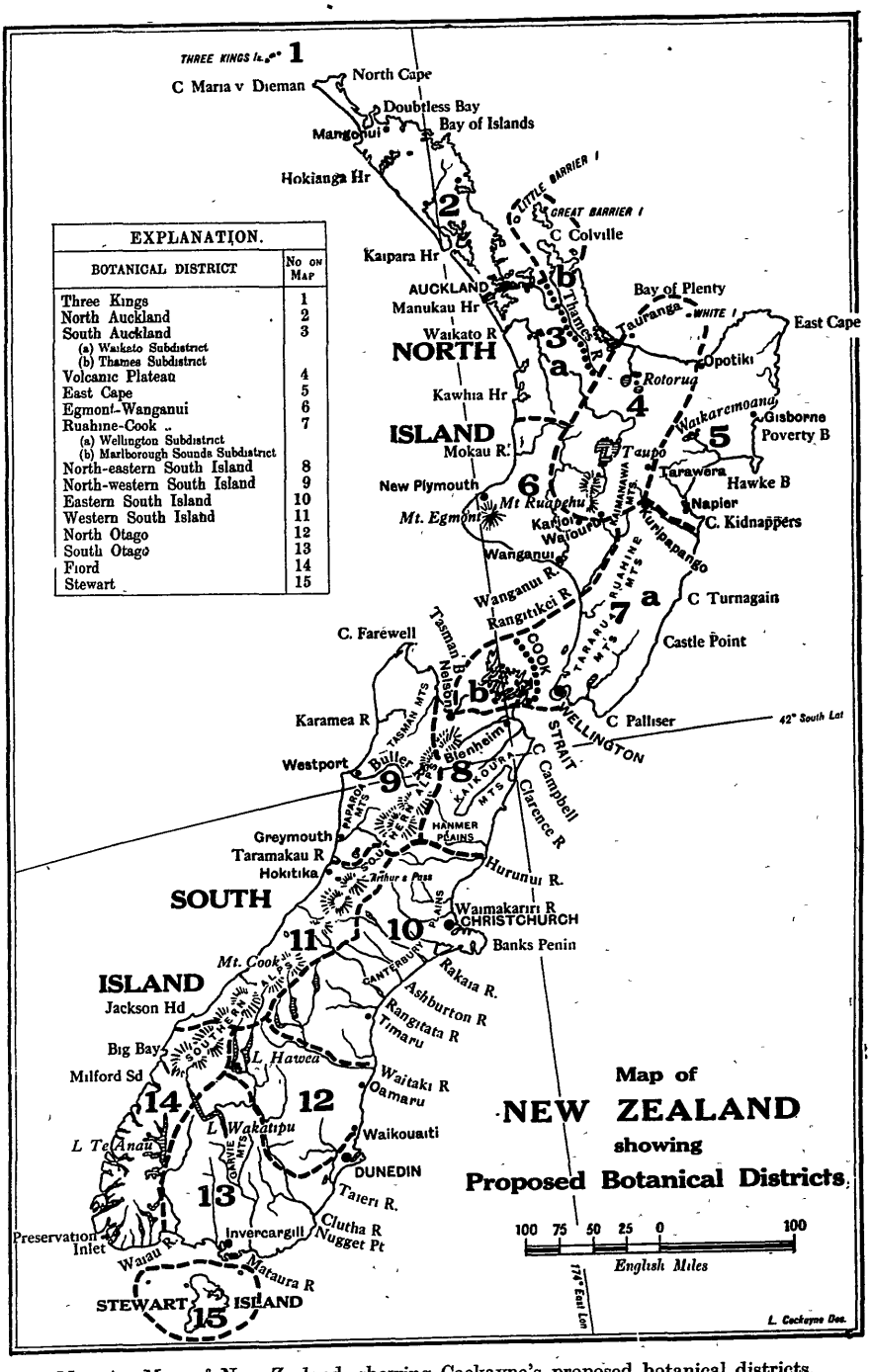
A. *South Island.*

In the neighbourhood of Dunedin, where the humidity conditions are similar to those prevailing on Banks Peninsula, and there is a comparative absence of the dry north-west wind, the taxad rain forest was originally widespread. For the period 1911–20 the average annual rainfall at Dunedin was 39·98 in., and the number of rainy days 155. From my own observations, and from the List of Species of this neighbourhood published by the Dunedin Field Club (17), it is apparent that the Hymenophyllaceae are here more abundant and also show a greater tendency to the epiphytic habit than in any of the existing Canterbury forests. Moreover, in the heavily forested gullies a few of the species range somewhat outside the actual creek-beds, and various species occur more luxuriantly still in the forests of the upper slopes of certain of the higher coastal hills where at altitudes of 1,000–1,500 ft. drifting mists are a well-marked feature. However, the extent to which they become epiphytic must be accounted quite restricted compared with their behaviour in the Westland forests. On the whole, the upland species are very poorly represented, and the same may be said of the especially hygrophilous section of the family. Thus the Dunedin forests may be classed on their Hymenophyllaceae as belonging to the lowlands, and their humidity may be reckoned to fall considerably short of the consistently high humidities of the forests of Westland.

T. Kirk (23) has published a list of Hymenophyllaceae occurring on Stewart Island, with short notes as to their relative abundance and their distribution. The rainfall at Half-moon Bay settlement, on the east coast, averaged for the period 1918 to 1920 60·85 in. per annum, and the number of rainy days 240·6. From the excessive number of rainy days it will readily be seen that the atmospheric humidity is for the most part high, a fact which Kirk points out is evident in the rapid change of vegetation into peat. The more elevated parts of the island, reaching an altitude of 3,200 ft., adjoin the west coast, and here the rainfall will be heavier. The forest-covering generally is heavy mixed-taxad rain forest, and is somewhat similar to that of Westland. *Nothofagus* is altogether absent. Kirk records the presence of twenty species of Hymenophyllaceae on Stewart Island, and notes that, whereas in New Zealand generally this family constitutes one-fifth of the entire fern flora, the proportion rises to one-third in Stewart Island. Thus Stewart Island may be more nearly compared with Westland as regards the filmy-fern flora than the forests of Banks Peninsula or of Dunedin. However, of the more hygrophilous species *T. Colensoi* and *H. scabrum* are apparently absent; *T. strictum*, *T. reniforme*, and *H. australe* are rare and local; and *H. dilatatum*, though fairly abundant, occurs on fallen logs rather than as an epiphyte. *Leptopteris hymenophylloides* and *L. superba* attain a luxuriant growth in secluded situations, but are much less widely distributed than in Westland. It is evident, therefore, that, although the climate of Stewart Island is humid, the humidity is not so favourable to the filmy ferns as in the forests of Westland, a fact which may very possibly be due to the greater prevalence of winds in Stewart Island.

The South Island North-western Botanical District presents favourable opportunities for a comparison of the distribution of the Hymenophyllaceae in heavy taxad and in pure southern-beech forests respectively under similar climatic conditions.

In the heavy taxad forests at Greymouth there is a distribution of the Hymenophyllaceae similar to that in the lowland forests of north Westland. A mile or so up the Grey Valley, immediately behind Greymouth, there is an extensive stretch of more or less flat pure *Nothofagus* forest in which there is a fairly abundant though noticeably restricted distribution of the Hymenophyllaceae. The rainfall here will be very little different from that at Greymouth, and the constantly high humidity near the ground in this southern-beech forest is attested by the fact that at low stations on the trees and on fallen logs I found an abundance of prothalli and sporeling plants of most of the species that were present. These are mainly the species which in the lowland Westland forest are mid and high epiphytes. *H. multifidum*, *H. sanguinolentum*, and *H. Armstrongii* clothe the main trunks of the trees up to a height of 20 ft. *H. dilatatum*, *H. scabrum*, and *T. reniforme* are all commonly present, as are *H. flabellatum*, *H. rarum*, and *H. Tunbridgense*, but all these are restricted to fallen logs or tree-bases up to 6 ft. above the ground. *H. demissum* is present upon the floor. The frequent presence of the upland *H. pulcherrimum* and *T. Lyallii* in a low epiphytic station is also an indication of the relatively high atmospheric humidity near the ground, but the specially hygrophilous *H. australe*, *H. ferrugineum*, and *T. strictum* are apparently absent. There are no mid-epiphytic ferns or other epiphytes other than the three species of *Hymenophyllum* first mentioned above. Pure southern-beech forest contains a very small admixture of large-leaved shrubs or shrubby trees, and



MAP 4.—Map of New Zealand, showing Cockayne's proposed botanical districts.

tree-ferns are scanty. The leaves of all the *Nothofagus* species are small, and the canopy and lower story are more open than are those of the heavier mixed-taxad forest. Thus under similar climatic conditions it would appear that whereas the atmospheric humidity of the interior of the heavy mixed-taxad forest is more or less consistently high up to the mid-epiphytic station on the trees, the same high humidity is maintained only up to the low epiphytic station in pure southern-beech forest.

This comparison may be even more strikingly made with regard to the southern-beech forests of the larger lowland valleys in the close vicinity of Reefton, which lie at an altitude of from 600 ft. to 700 ft. Here the mean annual rainfall for the period 1911–20 was 75·18 in., and the number of rainy days 174·7, so that the climate may fairly be considered a wet one. There is also an absence of drying winds. In these broad valley forests only six species of Hymenophyllaceae were found, of which *H. villosum* is the most abundant, occurring both as a low and a mid epiphyte, and occasionally also on the floor. In the narrower gullies *H. multifidum* also ascends to the mid-epiphytic station, and *H. rarum* is in occasional colonies on the underside of large overhanging trees. *H. demissum* and *H. Tunbridgense* are present on the floor. *H. ferrugineum* is also to be found very scantily on the damp rocky walls of the narrowest gullies. Tree-ferns, except for the low-growing *Alsophila Colensoi*, are noticeably absent. The forest-floor is very open, and, except for occasional *Asplenium flaccidum* and *Polypodium Billardieri*, epiphytic ferns are wanting. In the more secluded and damp gullies, however, *Leptopteris superba* and *L. hymenophylloides* are frequent, and I have here seen abundant colonies of the prothalli and sporeling plants of the former species. The hygrophilous *Blechnum nigrum* and *B. Patersoni* also occur frequently in these gullies. The scanty representation of Hymenophyllaceae in this southern-beech forest is in striking contrast to their more abundant occurrence in the heavy mixed-taxad and southern-beech forest on the adjacent hillsides at altitudes of 1,200 ft. to 1,500 ft. Here there is a close undergrowth of shrubs and tree-ferns. In addition to the six species mentioned above, the lowland *T. venosum* and *H. scabrum* and the upland *H. rufescens* and *T. Colensoi* are to be found commonly in gullies in their usual stations, and *H. ferrugineum* is abundant on the dripping gully-walls, while *H. flabellatum* and *H. bivalve* occur everywhere on banks and bases of old trees. Although a forested mountain-side at these altitudes is usually wetter than the forests of the lowlands, on account of the prevalence of the mountain mists, yet at Reefton this difference in the humidity will be largely compensated for by the fact that fogs in the lowland valleys are a frequent and persistent climatic feature. The very scanty distribution of the Hymenophyllaceae in the southern-beech forests must be attributed mainly, if not altogether, to the more open character of this type of forest as compared with that of the mixed and of the pure taxad forests.

Townson (31) has published a list of plants found by him in the Westport district, including fourteen species of *Hymenophyllum* and all of those of *Trichomanes*. It is to be noted that this list includes the two typically northern species *T. elongatum* and *T. humile*, both of which seem to be absent from Westland. From Townson's brief notes on some of the species it is evident that here the lowland species reach a higher altitude than in Westland, *T. reniforme* being said to occur up to 3,000 ft., and *H. ferrugineum* and *H. Tunbridgense* up to 2,000 ft. As will be seen below, in the neighbourhood of Nelson, and to a still greater

degree in the North Island, the lowland species generally have a much wider altitudinal range than in Westland, while, on the other hand, *H. villosum* becomes more restricted to the higher altitudes.

The position of Mount Hope at the junction of the wet North-western and dry North-eastern Botanical Districts is indicated by the fact that, while such species as *H. rufescens* and *T. Colensoi* and also certain wet-loving taxads are present, the Hymenophyllaceae are much restricted in their distribution, for the most part occurring either in the beds of gullies or on the overhung sides of the large granite blocks which are scattered over the forested slopes. As noted in my earlier paper, *H. Malingii* also occurs on these granite boulders at the upper altitudes, and especially on the ground in thick moss sheltered by them, in luxuriant and dense mats, a most unusual station for this species.

The ranges which lie immediately to the eastward of the Town of Nelson come well within the North-eastern Botanical District. At Nelson itself the average annual rainfall for the period 1911–20 was 36·37 in., and the number of rainy days only 116·5, the rain coming mainly from the northward. The dry south-west wind is a characteristic feature of the climate, being, on the whole, the most frequently occurring wind throughout the year. On the east of Nelson the ranges are from 2,000 ft. to 4,000 ft. in height, and are clothed to the summits with southern-beech forest. The Hymenophyllaceae occur mainly in the gullies and on the shady south-facing slopes. Here the lowland species ascend far higher than in Westland, *H. dilatatum*, *H. scabrum*, *T. reniforme*, *H. sanguinolentum*, and *H. Tunbridgense* attaining on rock-faces on the shady flanks, both in more open situations as well as in the gullies, an altitude of at least 3,000 ft. The comparatively humid character of these shady upland forests is shown also by the abundance, though always in a terrestrial or tree-base station, of the more widely ranging species *H. rarum*, *H. flabellatum*, *H. multifidum*, *H. villosum*, *H. demissum*, and *H. bivalve*. The two latter species occur exceedingly frequently, covering the floor of the forest everywhere in extensive sheets, *H. bivalve* showing a slight tendency, as usual, to climb tree-bases and fallen logs. On the highest ridges and peaks only *H. villosum* and *H. multifidum* are present. In the Nelson forests generally the more hygrophilous lowland species *H. australe* and *H. ferrugineum* are very locally distributed, while *T. strictum*, *T. Colensoi*, *T. Lyallii*, *H. rufescens*, *H. pulcherrimum*, and *H. Armstrongii*, all of which are abundant in the wet Western Botanical Districts, are apparently absent. *H. villosum* does not descend to so low an altitude as in Westland or Canterbury.

On account of the higher altitude attained by the lowland species in the Nelson forests than in those of Westland, there is not here, generally speaking, so well-marked a differentiation in the regional distribution of the family. However, this can still be seen quite clearly in certain of the large forested gullies which lie on the unshaded north-facing hill-flanks, where the lowland species are altogether confined to the lower more sheltered reaches, even there being found on rock-faces rather than as epiphytes, while, on the other hand, the wider-ranging species mentioned above are abundant on the floor in the upper parts of the gullies, where these open out at an altitude of 1,500 ft. and upwards under the ridges and hill-shoulders. The dampness of the forest-floor at the higher altitudes in such valleys will be due to the sea-mists which frequently gather against the hillsides in the vicinity of Nelson, and this effect will be still more marked on the shaded mountain-sides on to which, as has been described above, the lowland species are able to ascend.

B. *North Island.*

With regard to the distribution of the Hymenophyllaceae in the North Island, the most outstanding feature to be mentioned is the high altitude attained by the lowland species generally. In the northern part of this Island, where there are only one or two mountains of as great an altitude as 3,000 ft., there is practically no distinction to be traced between lowland and upland species. In a description of the plant-covering of Te Aroha Mountain (3,176 ft.), at the southern extremity of the South Auckland Botanical District, J. Adams (1) remarks that the humidity of the top of the mountain makes it one of the most favourable localities for ferns, and he shows that the Hymenophyllaceae, including such species as *H. dilatatum*, *H. scabrum*, *T. reniforme*, and *H. australe*, are to be found for the most part at the summit. The same observer has reported *T. reniforme* and *T. venosum* from the summit of Te Moehau Mountain (2,750 ft.), on the Cape Colville Peninsula (2). For this reason the altitudinal range of many of the species as given by Cheeseman (10) will be far greater than what it is found to be in Westland or in other parts of southern New Zealand. In the more mountainous parts of the North Island, as in the South Island generally, *H. villosum* and *H. multifidum* ascend to higher altitudes and into more exposed positions than any other of the species. For example, J. Adams (3) has noted the occurrence of the former species on the open summit of Mount Hikurangi, in the East Cape District, at an altitude of 5,600 ft. In his Botanical Report on the Mount Tongariro National Park (13), which lies at an altitude of 3,000 ft. and upwards, L. Cockayne frequently refers to *H. multifidum* along with the hardy *Polystichum vestitum* and *Blechnum penna marina* as being the ferns which most affect the physiognomy of the southern-beech forest-floor, the *Hymenophyllum* being the most conspicuous of the mat-forming plants.

Several members of the family do not extend into the northern part of the North Island. According to Cheeseman (10), *H. pulcherrimum*, *H. peltatum*, *H. Malingii*, and *H. rufescens* reach their northern limit on Te Aroha Mountain, *H. villosum* on Mount Te Moehau, and *T. Colensoi* in ravines near Rotorua. All these are typical upland plants, and their absence from the north may be due simply to the fact that there are no high elevations to be found in that part of New Zealand. It is to be noted that the northern limit for *H. Malingii* is the same as that for *Libocedrus Bidwillii*, to which it is almost invariably restricted. Cheeseman does not record *H. minimum* from the North Island. This species is distributed, though somewhat discontinuously, throughout the South Island; it was said by T. Kirk (23) to be not infrequent in Stewart Island, and it is present also on Auckland Island (27). From these facts it would appear to be a southern plant. Oliver (2), however, has also reported it from Lord Howe Island, off the coast of New South Wales, so that there seems to be no reason for its apparent absence from the North Island. *T. elongatum* and *T. humile* are both abundant species in the Northern Botanical Districts of the North Island, and extend, though more sparsely, throughout its Southern Districts and even into the Northern Districts of the South Island. They both occur in the islands of the Western Pacific Ocean, and so may be regarded as belonging to the Malayan and Polynesian element in the New Zealand flora.

Various writers have commented upon the luxuriance of the shrubbery and other low-growing vegetation on the scoria-fields of the Auckland

Isthmus, and especially on the volcanic islet of Rangitoto, in the Auckland Harbour. Amongst other epiphytic ferns and typical forest-epiphytes growing upon the scoria, various species of Hymenophyllaceae attain a great luxuriance. T. Kirk (21) has noted the abundance of *H. australe* and *T. humile* amongst the shrub-covered scoria-blocks on the mainland, remarking that this provides a striking proof of the high atmospheric humidity in these localities. This fact gains added significance when it is remembered that these particular species are amongst the most hygrophilous in the family. Other writers have drawn attention to the fact that *H. sanguinolentum* and *T. reniforme* occur abundantly on the scoria-blocks on the slopes of Rangitoto Island in the full blaze of the sun. During the heat of the summer the fronds of these two species are shrivelled and are apparently dead, but with the autumn rains the plants are as green as ever. I have found here *H. multifidum* growing frequently side by side with the two other species; and in the damp gullies in the scoria slopes, shaded by the shrubbery, are *H. dilatatum, H. scabrum, H. Tunbridgense, H. australe,* all on the ground, *H. flabellatum* as a low epiphyte, and *Tmesipteris* on tree-fern stems. It may be added that many other forest-epiphytes are found on Rangitoto Island growing on the scoria, such as the orchids *Bulbophyllum pygmaeum, Earina mucronata,* and *Dendrobium Cunninghamii,* and the shrubby epiphyte *Senecio Kirkii. Psilotum triquetrum* is most abundant at the lowest levels. From the official data these is no doubt that Auckland possesses a very humid climate. The average annual rainfall at Auckland City for the period 1911 to 1920 was 49·32 in., and the number of rainy days 195·3. The mean humidity for the same period was 79·7—that is to say, 3·4 higher than at Hokitika, in Westland. There is no doubt also that the scoria-blocks, and the humus in their interstices, absorb and hold much dew as well as rain-water. The humidity of the climate is also seen in the fact that the tree-fern *Cyathea medullaris* is commonly grown in the open in the city private gardens. Nevertheless the exposed position on Rangitoto Island occupied by such a species as *T. reniforme* is remarkable. This species is able to hinder transpiration by the inrolling of the frond. In the forests of Westland *T. reniforme* is able to endure as a middle epiphyte rather more exposed positions than the two other species usually associated with it, viz.—*H. dilatatum* and *H. scabrum;* and elsewhere in New Zealand it is sometimes to be found in sheets on the floor of southern-beech forests unaccompanied by the latter. On the other hand, in the neighbourhood of Dunedin, and also in Stewart Island, *H. dilatatum* is abundant and luxuriant while the other two species are scanty or absent.

I have been able to examine the forests on the eastern side of the North Auckland Peninsula at various places, and have observed that, generally speaking, the Hymenophyllaceae are more restricted to low epiphytic stations or to the floor than they are in the Westland lowland forests, or than they are, as Mr. Cheeseman informs me, in the gullies on the low western ranges of Auckland. This will probably be due to the lighter character of these eastern forests in North Auckland. As described in my previous paper, *T. elongatum* and *T. humile* form a very characteristic association on the creek-bed walls of these forests.

C. *The Outlying Islands.* (See map 1, on page 68.)

The Kermadec Islands, which lie to the north-east of New Zealand, are a widely-separated group, of which the largest island, Raoul or Sunday

Island, is distant about six hundred miles from New Zealand. Sunday Island rises to a height of 1,720 ft., and is the only one of the group which is forest-covered. The plant-covering of this island has been described by two New Zealand botanists, Cheeseman (9) and Oliver (28). The last named, who spent a year on the island, describes the climate as mild and equable, with many rainy days, considerable precipitation evenly distributed over the year, much wind in the winter months, and a constantly humid atmosphere. For the nine months February to October, 1908, the total rainfall was 67·5 in., on 176 days; and the mean humidity was 91. The more elevated parts of the island are frequently enveloped in mist, and the plant-covering here is designated by Oliver "wet forest." There are, however, no permanent streams. Four species of Hymenophyllaceae occur in the wet forests, and the following description of them is taken from Oliver's paper (p. 142): *H. demissum* is abundant everywhere in wet forest, on branches of trees, tree-fern stems, and on the ground. *H. flabellatum* is found in one place only, on the highest summit, the matted roots and close fronds covering the underside of a leaning trunk of *Metrosideros villosa*. *T. humile* is extremely rare, being found only on wet banks and fallen trunks of tree-ferns in deep shady ravines. *T. venosum* is an epiphyte of the wet forest found on the underside of leaning trunks of *Cyathea kermadecensis*. The high humidity of this upper forest is shown by the luxuriant epiphytic vegetation there to be found on leaning trunks and horizontal branches and on the tree-fern stems. The Kermadec Islands as they now exist are of volcanic origin, and the consensus of opinion seems to be that they are oceanic —at any rate, in a biological sense. The flora is closely allied to that of New Zealand, but there is also a considerable number of subtropical species. The four species of Hymenophyllaceae are all abundant in the North Island of New Zealand. The scanty distribution of this family in the Kermadecs is the more remarkable when the favourable nature of the forest is considered. From a study of the flora generally, Cheeseman concludes (9, p. 163) that the islands have been stocked with their plants by chance migrations across the ocean.

The Chatham Islands lie about five hundred miles due east from New Zealand, in the latitude of Banks Peninsula. The largest of these is about thirty miles in length, its surface consisting, on the whole, of low elevations, relieved here and there by hills, of which those in the south attain a height of 600–940 ft. Forest covers a certain portion of the main island, both in the lowland and on the higher elevations, that of the latter being especially humid, with a close undergrowth of tree-ferns in many places and with an abundance of epiphytic ferns. Two papers dealing with the plant-covering have been published in the *Transactions of the New Zealand Institute*, the first by Buchanan (6), who gave merely a list of plants collected from the main island, and the second by L. Cockayne (11), who dealt with the subject from an ecological point of view. The latter gives figures showing that at the eastern coast-line the average annual rainfall is 30·4 in., but that it is distributed over 186·6 days in the year, and adds that the rainfall is certainly heavier on the higher southern portion of the island. After going into the subject of the climate in detail he concludes that it must be reckoned exceedingly mild and equable, but that the winds are very frequent. Buchanan's list of Hymenophyllaceae occurring on the main island is as follows: *H. bivalve, H. demissum, H. dilatatum, H. australe, H. flabellatum, T. reniforme,* and *T. venosum;* to which Cockayne

has added *H. multifidum*. In his description of the higher-altitude forest the last-mentioned writer states that here every tree-trunk, tree-fern stem, and dead tree is covered with multitudes of filmy ferns. Epiphytic on the tree-fern stems are *T. venosum*, *H. multifidum*, *H. dilatatum*, and *T. reniforme*. The filmy ferns are often so thick that they completely hide the trunk of tree or fern on which they grow. In many cases the ground also is covered with a thick carpet of them. In deep forest-clad gullies *T. reniforme* often grows with extreme luxuriance. Cockayne concludes (p. 314) that, although lacking the most characteristic forest-trees of New Zealand, the flora of the Chatham Islands must be considered a recent offset from that of New Zealand, and he notes that the geological and zoological evidence is in favour of a former land connection. In view, however, of the absence of so many characteristic New Zealand genera, he cites Cheeseman's view of the origin of the flora of the Kermadec Islands.

The remaining outlying islands to be considered are those usually designated the Subantarctic Islands of New Zealand—viz., the Auckland, Campbell, Antipodes, and Macquarie Islands—which lie easterly or southerly from the South Cape of New Zealand at distances of 190 to 570 miles (see map 1, on page 68). The plant-covering of the two first-named groups was in part described by J. D. Hooker (19), and of all except the Macquarie Islands more fully by L. Cockayne (12). In 1907 all of the groups were thoroughly investigated by the New Zealand Scientific Expedition, and a full account published (27).

The following brief account of the climate and forest-covering of Auckland Island is taken from Cockayne: There are many rainy days, almost constant cloudy skies, very frequent winds which are sometimes of great violence, and a winter climate which is extremely mild—much milder, indeed, than that of certain parts of the South Island of New Zealand at sea-level, as, *e.g.*, the Canterbury Plains. The rata-forest zone forms a belt extending round a considerable portion of the coast of the various islands in the Auckland Group, being more luxuriant, with a richer fern flora at the heads of sheltered inlets. At altitudes of about 400 ft. it gives place to formations of scrub or meadow. The floor of the forest consists of wettish peat. The mechanical effect of the constant and heavy winds has produced a semi-prostrate, stunted and gnarled forest, but owing to the moist mild climate the trees are luxuriantly branched. The canopy of the forest, rising about 15 ft. above the ground, is very dense and keeps the interior calm, and this, combined with the great amount of moisture in the atmosphere, affords very strong hygrophytic conditions in its interior. There is a luxuriant growth of mosses, liverworts, and filmy ferns both on the floor and on the trunks and branches of the trees, and amongst other ferns the strongly hygrophilous *Leptopteris superba* is to be found in favourable localities.

Ten species of *Hymenophyllum* have been recorded from the Auckland Island rata forest—viz., *H. rarum*, *H. sanguinolentum*, *H. villosum*, *H. dilatatum*, *H. demissum*, *H. flabellatum*, *H. minimum*, *H. Tunbridgense*, *H. multifidum*, and *H. bivalve*. It will be noticed both that the above list includes the six species which on the main islands of New Zealand show themselves to be the least hygrophilous and the most consistently wide-ranging in the family, and also that it contains no species of *Trichomanes*. However, the presence of such comparatively hygrophilous species as *H. dilatatum*, *H. sanguinolentum*, and *H. Tunbridgense* is a striking proof

of the consistently high humidity of the forest-interior. *H. multifidum* is by far the most abundant species, occurring in the rata forest in its ordinary mesophytic form. On Campbell Island there is no forest, its place being taken by a dense scrub-association. The only Hymenophyllaceae here occurring are *H. villosum* and the mountain form of *H. multifidum*, the latter occurring, as in the Auckland Islands, in large abundant patches both in the subalpine meadow and on subalpine rocks. On the Antipodes Island *H. multifidum* alone has been found, while on Macquarie Island, where woody plants are altogether wanting, even this species seems to be absent. Cockayne points out (12, p. 271) that these Subantarctic Islands can be arranged in a series affording an instructive example of how arborescent plant-formations, even in a rain-forest climate, are inhibited by frequent and violent winds, and their place taken by meadow growths, which, notwithstanding the winds, are so stimulated by the moisture as to be of very great luxuriance. In the same way this series indicates *H. villosum* and *H. multifidum* as being the hardiest species of the Hymenophyllaceae, as also they are seen to be on the mainland of New Zealand.

III. General Conclusions.

1. The conclusions reached as to the altitudinal distribution of the Hymenophyllaceae in Westland, set forth in Part I of these Studies (18), are borne out by their behaviour in the drier parts of the South Island, and in other parts of the New Zealand Biological Region, except that northward the lowland species attain progressively higher altitudes.

2. The conclusions reached as to the vertical distribution of the species in the Westland forests (18) are also borne out by their behaviour in other parts of the New Zealand Biological Region, except that nowhere do they so thoroughly adopt the epiphytic habit as they do in Westland.

The comparative study of the fern floras of the forests of different localities shows that the extent to which the ferns generally and the Hymenophyllaceae in particular adopt the epiphytic habit is a reliable indication as to how far the high humidities in the forest-interior can be regarded as consistent.

3. Those species which in the comparatively dry Eastern District of the South Island have the widest altitudinal range—viz., *H. villosum* and *H. multifidum*—and which, along with *H. peltatum* and *H. sanguinolentum*, must be reckoned to occur there the most abundantly, are always the first to begin to adopt the epiphytic habit.

4. The comparison of the heavy mixed-taxad and the pure southern-beech types of forest in localities where, as in the vicinity of Reefton, these occur in close proximity shows that the latter, on account of its poverty in large-leaved shrubs and shrubby trees and tree-ferns, is unable to preserve in its interior, except perhaps at or near the floor, a constantly high atmospheric humidity even when the rainfall and the number of rainy days experienced is large; and also that it is unable to afford favourable epiphytic stations for the majority of the Hymenophyllaceae, on account of the absence from it of large irregularly-shaped tree-bases and low-spreading horizontal branches. It is possible that it is mainly on account of this latter reason that the eastern forests of North Auckland also do not show such an abundant filmy-fern flora as do the forests

of Westland, although the atmospheric humidity in the former remains undoubtedly high.

5. It was shown (18) that in Westland a large proportion of the species occur in groups according to their habits. These natural groups can be recognized also in other districts of New Zealand; but differences between the members of a group are shown by the manner of their response to varying climatic conditions in lighter types of forest, which differences are in some cases discernible also in their behaviour in the forests of Westland.

6. The species, both lowland and upland, including nearly all those of *Trichomanes*, which were shown (18) to be in the Westland forests the most hygrophilous of the family are either altogether absent from the drier forests of Canterbury and Nelson or are the most locally distributed.

7. The geographical distribution of the family in the New Zealand Biological Region is to be seen with respect to several of the species. *T. humile* and *T. elongatum*, both abundant in the north, become less so farther south, and in this direction do not extend beyond the northern parts of the South Island, Banks Peninsula being apparently their southern limit. These two species belong to the Malayan element in the New Zealand flora. On the other hand, the following species—viz., *H. pulcherrimum*, *H. peltatum*, *H. Malingii*, *H. rufescens*, *H. villosum*, and *T. Colensoi*—all of which, with the exception of *H. Malingii*, which occurs also in Tasmania, are endemic to New Zealand, find their northern limit, together with certain upland phanerogams, at or about the extreme southern end of the South Auckland Botanical District. These species are typical upland plants, and it may be that their absence from the northern part of the North Island has no phytogeographical significance, but is due to the absence from those parts of mountains of any considerable elevation. *H. minimum*, so far as the New Zealand Biological Region is concerned, seems to have its centre of distribution in the extreme south, but it has also been reported from Lord Howe Island.

8. The outlying islands of the New Zealand Biological Region do not possess any Hymenophyllaceae which are not present in New Zealand itself, and, judging from the composition of their filmy-fern flora, the occurrence in them of members of this family would seem to have resulted rather from chance dispersal from New Zealand or from elsewhere than from the effect upon a once larger number of species of a changing climate due to a shrinking and subsiding land-area. Of the endemics, *H. villosum* occurs in the Auckland and Campbell Islands, and *T. reniforme* on Chatham Island.

9. Of the nine species which are endemic to the New Zealand Biological Region, three—viz., *H. villosum*, *H. rufescens*, and *H. atrovirens*—can possibly be regarded as specialized forms of other species also present in New Zealand—viz., *H. sanguinolentum*, *H. flabellatum*, and *H. australe* respectively. *T. strictum* is said to be most nearly related to the widely-spread *T. rigidum*. With regard to *H. minimum*, J. D. Hooker (20, p. 104) has suggested the cosmopolitan *H. Tunbridgense*, or the Polynesian *H. multifidum*, or the Fuegian *H. caespitosum* as the species to which this plant is most closely allied. Concerning the remaining endemic species nothing can here be suggested as to their possible affinities, but it must be noted that they are all very distinct from other New Zealand species and are markedly specialized.

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